Modelling timber offcuts utilisation: a case study in Victoria, Australia

Mohammad Reza Ghaffariyan, Mark Brown

Mohammad Reza Ghaffariyan, Forest Industries Research Centre, University of the Sunshine Coast, Locked Bag 4, Maroochydore DC, Queensland, Email: mghaffar@usc.edu.au; ghafari901@yahoo.com
Mark Brown, Forest Industries Research Centre, University of the Sunshine Coast, Locked Bag 4, Maroochydore DC, Queensland, Email: mbrown2@usc.edu.au

Corresponding author: Mohammad Reza Ghaffariyan (mghaffar@usc.edu.au; ghafari901@yahoo.com)

Abstract

This study evaluates the economic potential of utilizing timber offcuts for bioenergy in Victoria, Australia. Timber residues, often sent to landfills, present an opportunity for revenue generation through bioenergy production. We assessed chipping productivity and transportation costs, utilizing the Vermeer BC1500 chipper, which yielded an average productivity of 7.5 t/PMH and a cost of $25.5/t. Transportation was modelled using a small woodchip truck with payload of 10 t over distances ranging from 30 to 100 km. Results indicate transport costs increased from $1.5/t to $5.0/t with distance. Profitability analysis revealed that transporting wood chips is still viable up to 100 km, with average profits decreasing as distance increases. This research underscores the economic benefits of biomass recovery, highlighting potential savings of $170/t compared to landfill disposal, thereby promoting sustainability in offcuts utilisation.

Keywords
Timber offcut, Biomass, Chipper, Truck, Productivity, Cost

Introduction

Timber residues are by-products of timber harvesting and processing operations in plantations and timber companies. Currently, most timber residues produced at mills are transported to landfill facilities which may cause high disposal costs associated

with environmental risks. Turning woody residues to revenues through generations of bioenergy, biochar or other types of bioproducts can provide innovative solutions to reduce the waste management cost, gain further economic benefits and enhance their sustainability profile in terms of mitigating environmental impacts (De Klerk et al. 2022). Utilisation of timber residues have been previously studied in various regions of the world. European technologies mainly focus on the application of forwarders and farm tractors to remove forest harvesting residues to roadside. Then in-field chippers and grinders are applied to process the forest harvest residues into wood chips (Kühmaier et al. 2022; Moskalik and Gendek (2019)). According to Roeser et al. (2012) in some countries such as Scandinavia, the harvesting residues can be collected and bundled using slash bundlers to be transported to mills for application in bioenergy facilities after chipping. The other option in Sweden is to concentrate forest harvesting residues at the roadside then truck-mounted or forwarder-mounted chippers are applied to chip residues into trucks. In North America, the forest harvesting residues are usually pilled at roadsides or landings and then chipped directly into chip vans (Jacobson et al. (2019); Kizha and Han (2015)).

This case study was initiated as a timber processing company currently utilises the briquettes from a kitchen manufacturer in Bendigo (Victoria, Australia) as they financially assist with the delivery. Other wood resources closer to the Poowong region in Victoria are delivered free of charge. The timber company is interested in utilizing timber off-cuts to chip and deliver them into potential sites for bioenergy utilisation. This will help the company reduce and manage timber residues and improve their sustainability footprint while contributing to renewable energy generation in the country. To utilise timber offcuts for bioenergy purposes this study was conducted to understand the efficiency and costs as there has been little information available on this type of biomass recovery in Victoria. This research aimed to achieve the following objectives:

- Find a suitable chipper type and predict the cost of in-field chipping operation.
- Model the transportation cost for various scenarios including different distances and truck capacity/payload.
- Evaluate the profit gained for various scenarios.

Study site

The study site was in Poowong, Victoria which was chosen to evaluate the economics of utilising timber offcuts. The average wood size of timber offcuts was 0.0005 m3 (average). The size varied from 0.0003 to 0.002 m3.

Methods

Chipping is an important component of some timber supply chains used to produce wood chips for biomass and pulp. The raw materials for chipping can be forest harvesting residues, pulpwood, energy wood or whole trees and mill woody residues. Chipping productivity and cost depend on tree size, chipper power, chip discharge
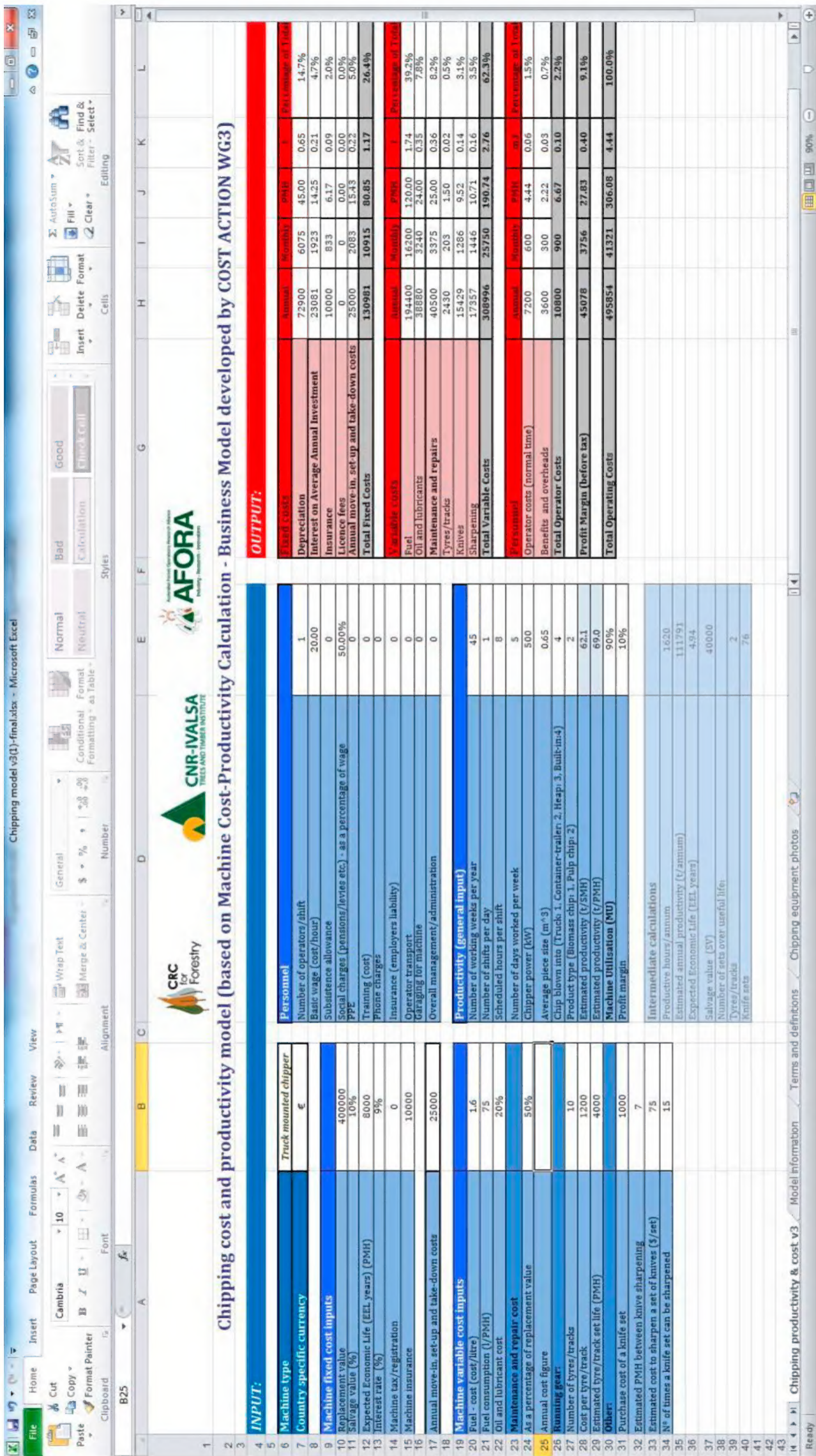
Fig. 1. Excel-based chipping model spreadsheet

place and type of product according to the chipping productivity model predicting developed by Ghaffariyan et al. 2013 based on 205 chipping time study information in Australia and Italy. This Excel-based chipping model spreadsheet (Figure 1) calculates the machine cost and unit cost using the standard machine cost and productivity calculation. The inputs include machine type, machine fixed cost, machine variable cost, personnel and productivity. The outputs are annual, monthly, hourly and unit costs classified in four sections including fixed, variable, personnel and total costs. The above-mentioned model was applied to find a suitable chipper and predict the productivity and cost of chipping.

Timber transport is one of the main components of the wood supply chain, which causes high costs and considerable emissions depending on truck size, type, transport distance, and payload (Small and Ghaffariyan, 2023). Transporting wood products by timber trucks is costly due to the long travel distances between plantations and mills (Acuna et al. 2012; Brown and Ghaffariyan, 2016). Transportation costs account for more than 25% of forestry costs (Svenson and Fjeld, 2016). Higher operating costs may occur due to increased fuel costs.

A previous transport cost predicting model for woodchips developed by University of the Sunshine Coast, Australia (Ghaffariyan et al. 2013) was modified to apply in this case study. To predict the transport cost, two variables were considered including transport distance and truck payload. Transport distance (one-way) ranged from 20 km to 100 km for small woodchip trucks (payload of 10 tonnes) in this case study. Then using a statistical transport cost predicting model (based on linear regression type model) the values for transport cost for various range of transport distances. A cost benefit analysis was conducted based on calculations of the total cost (sum of chipping and transport) and price of biomass at mill gate. The profit per tonne was calculated by subtracting total cost per tonne from price. The profit per tonne was used to determine allowable transport distance for this case study.

Results

Modelling chipping productivity and cost

Basic machine and timber information

The following information (Table 1) was used to predict the productivity and cost of the Vermeer BC1500 Chipper. Considering the small size of wood offcuts, this chipper type could be suitable as its engine power and purchase price sounds reasonable.

This chipper has similar power to other applied ones in the area, such as the Eeger Beever 1621X Brush Chipper, which was also considered in the assessment.

Chipping performance modelling

The chipping cost predicting model was run for the Vermeer BC1500 Chipper (Figure 2) considering the mentioned values assumed for the machine, wood size and

Table 1. Chipping data used for predicting the productivity and costs

Parameter	Value
Power	130 hp (97 kW)
Machine replacement value	approximate $ 84,000
Fuel consumption	44.3 litres per hour
Wood size	0.0005 m^3 (average), Range: 0.0003 to 0.002 m^3
Chip blown into place	Truck
Product type	Biomass

Fig. 2. Vermeer BC1500 Chipper (https://www.vermeeraustralia.com.au)

operation type to produce biomass chips. For the average offcut wood size of 0.0005 m^3, the model predicted a productivity of 7.4 tonnes per productive machine hour (t/PMH_0) and a cost of 25.5 $/t. By varying offcut wood size from 0.0003 to 0.002 m^3 machine productivity increased from 7.4 to 7.5 t/PMH_0. A sensitivity analysis was also conducted to see the impact of wood size on chipping cost. The result is illustrated in Figure 3. Larger wood sizes resulted in higher machine productivity which reduced the chipping cost per tonne slightly. According to the chipping productivity and cost model results (Ghaffariyan et al. 2013) chipping directly into trucks (applied in this case study) is more productive than other alternatives such as blowing chips into container-trailers, heaps or built-in units.

An Eeger Beever 1621X Brush Chipper with an engine power of 106 kW was also used to predict chipping performance. According to the chipping cost predicting model, its productivity averaged at 7.9 t/PMH with an average cost of 26.8 $/t. The cost is slightly higher than Vermeer BC1500 Chipper.
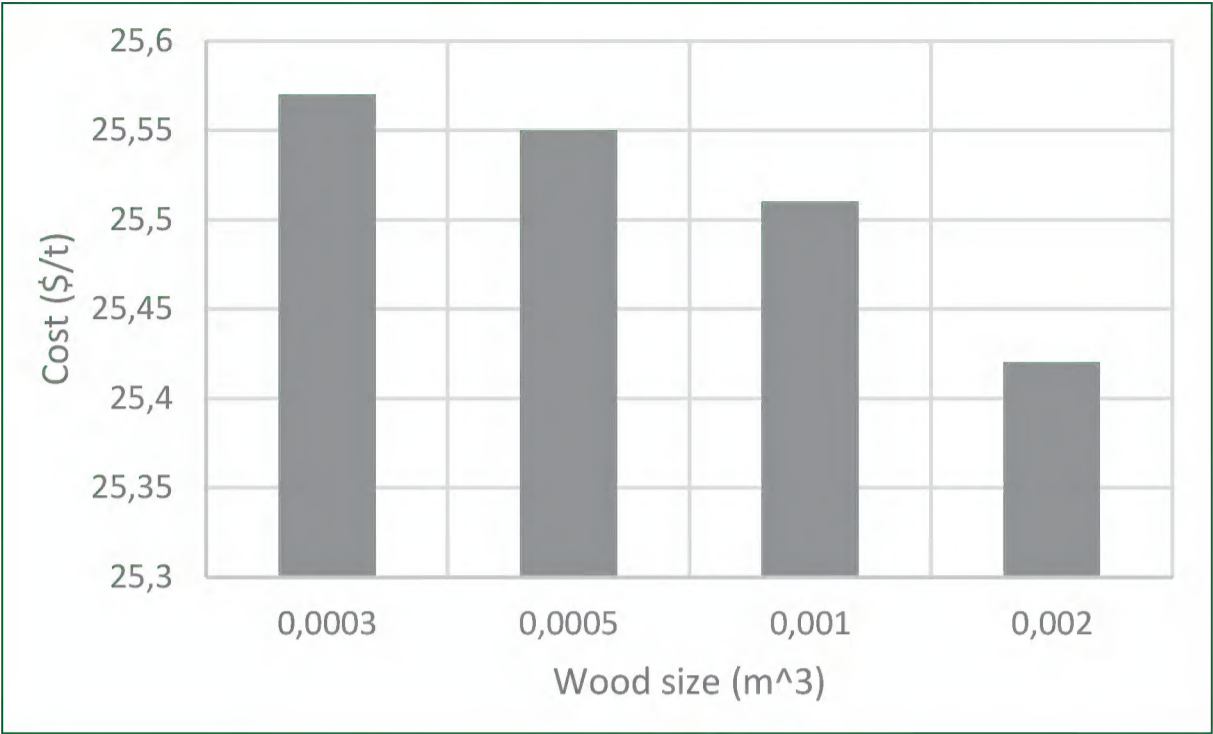
Fig. 3. Predicted chipping costs for various offcut wood sizes

Estimating transport cost

A small woodchip truck (with payload of 10 t) was chosen for the woodchip transportation task (Figure 4). A 10-tonne truck can transport wood chips over short distances easily, such as from a wood processing facility to a nearby construction site, storage yard, or factory. Urban roads and well-maintained regional highways are well-suited for trucks of this size.

For this case study, a cost of $0.50/t-km was assumed for the application of a 10 tonne truck. Increasing the transport distance from 20 km to 100 km resulted in an increase in transport cost from 1.5 to 5.0 $/t due to the increase in travel time (Figure 5). This corresponds to a 0.56 $/t increase in transport costs for any increase of 10 km in transport distance.

Cost benefit analysis

To conduct the cost benefit analysis, the total cost was calculated by summing up the chipping and transport cost per each tonne (note that companies might have extra overhead costs to add depending on their management conditions). A price of 35 $/t was assumed for the delivered biomass at customer mill gate (e.g. bioenergy or biochar company). Then profit per tonne was calculated for various transport distances and payloads. The results are summarised in Table 2. The average profit for transporting wood chip biomass was 6.3 $/t for a range of distance varying from 30 to 100 km while total costs of chipping and transportation averaged at 28.8 $/t. Increasing distance from 30 km to 100 km reduced the profit by 44% from 8.0 to 4.5 $/t. Any transportation longer than 100 km will result in low profit that could be avoided if economic gain is the main objective.

Fig. 4. Small woodchip tipper (https://www.duralloy.com.au/blog/woodchip-tipperrgm-maintenance/)

Table 2. Profit for wood chip biomass production over different transport distances

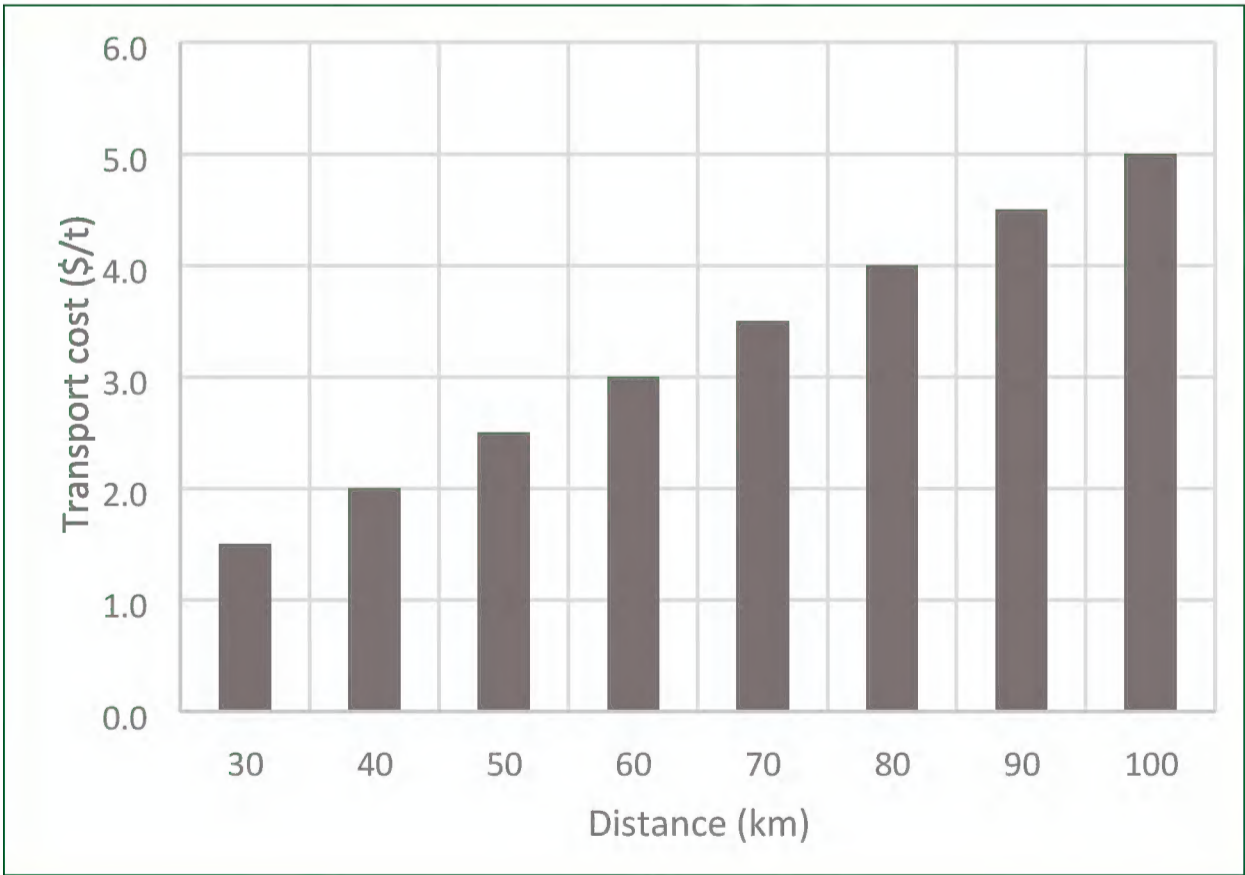| Transport distance (km)	Profit ($/t)
30	8.0
40	7.5
50	7.0
60	6.5
70	6.0
80	5.5
90	5.0
100	4.5

Fig. 5. Impact of transport distance on transport cost of wood chips

Landfill costs in the study area averaged at 200 \$/t. The supply chain costs for recovering timber offcuts for bioenergy was estimated at 30 \$/t. Thus, recovering timber offcuts for bioenergy can assist saving 170 \$/t compared with conventional landfilling.

Discussions

The average chipping productivity for both chippers in processing timber offcuts in this case study was about 7.5 to 7.9 t/PMH_0 which is lower than other studies in Australian forest operations such as the Husky Precision 2366 chipper (engine power of 441kW with average productivity of 50.7 t/ PMH_0 for chipping whole Eucalypt trees with volume of 0.1 m^3 (Ghaffariyan et al. 2012)), the Bruks 805.2 STC mobile chipper (engine power of 336 kW with average productivity of 43.9 t/ PMH_0 for chipping residue logs with volume of 0.3 m^3 (Ghaffariyan et al. 2012)) and the Morbark B12 truck-based chipper (engine power of 368 kW with average productivity of 59.4 t/ PMH_0 for chipping pulpwood logs with volume of 0.1 m^3 (Ghaffariyan et al. 2012)). The difference in productivity is due to the small engine power (97-106 kW) and very small piece volume (0.0005 m^3) in our case study. The chipping productivity found in our case study is consistent with the Italian small chippers and tractor-powered chipper which produced 2-5 t/PMH_0 with engine power ranging from 75 to 150 kW (Spinelli and Hartsough 2001).

Conclusions

Considering the small size of timber offcuts in this case study, small size chippers can be suitable machines to apply. Only a small volume of timber offcuts resulted in slightly higher chipping costs and lower chipping productivity. To reduce the transport cost and increase profit it is recommended to consider short-medium transport distances (30 to 90 km). Long transport distances (e.g. > 110 km) should be avoided during logistics planning of offcuts biomass utilisation, establishing new biomass/bioenergy plants or finding new customers. The application of high-capacity trucks will require larger volumes of wood chips in the management area to be viable alternatives for transporting which can be investigated further in the future (Kärhä et al. 2023; Small and Ghaffariyan, 2023; Higgins et al. 2017).

This study highlighted that recovering timber offcuts for renewable energy can provide significant savings compared with costly landfill alternatives. Cost and productivity figures used in this study are based on research observations and scientific models. Industry users may adopt the cost models based on their own local information. Future research could study the economic feasibility of other supply chain scenarios such as concentrating timber offcuts at a central yard then chip to deliver to end-user point or delivering timber offcuts using skip bins to chip at end-user point.

Acknowledgements

References

Acuna M., Mirowski L., Ghaffariyan M.R., Brown M. 2012. Optimising transport efficiency and costs in Australian wood chipping operations. Biomass and bioenergy, 291–300.

Brown M., Ghaffariyan M.R. 2016. Timber truck payload management with different in-forest weighing strategies in Australia. Croatian Journal of Forest Engineering, 131–138.

de Klerk S., Ghaffariyan M.R., Miles M. 2022. Leveraging the entrepreneurial method as a tool for the circular economy: the case of wood waste. Sustainability 14, 1559. https://doi.org/10.3390/su14031559

Ghaffariyan M.R., Acuna M., Brown M. 2013. Analysing the effect of five operational factors on forest residue supply chain costs: A case study in Western Australia. Biomass and Bioenergy 59, 486–493

Ghaffariyan M.R., Sessions J., Brown M. 2012. Evaluating productivity, cost, chip quality and biomass recovery for a mobile chipper in Australian roadside chipping operations. Journal of Forest Science 58 (2), 530–535.

Ghaffariyan M.R., Brown M., Acuna M., Sessions J., Kühmaier M., Wiedemann J. B2011. Biomass harvesting in Eucalyptus plantations in Western Australia. Southern Forests 73 (3&4), 149–154

Ghaffariyan M.R., Spinelli R., Brown M. 2013. A model to predict productivity of different chipping operations. Southern Forests 75 (3), 129–136

Griffin R., Brown M. 2010. Forest truck fuel consumption survey. CRC for Forestry Bulletin 8, April 2010, 3 pp.

Higgins A., Marinoni O., Pinkard L., McFallan S., McKeown A., Bruce C. 2017. TraNSIT: Modelling the supply chain of Australia's plantation forestry. Australia: CSIRO, 30 pp. https://www.duralloy.com.au/blog/woodchip-tipper-rgm-maintenance/ https://www.vermeeraustralia.com.au

Jacobson J., Zamar D., Ebadian M., Yazdanpanah F., Sokhansanj S. 2019. Supply of wood pellets to coal-fired power plants in Alberta. IEA Bioenergy Task 43, 2018: 06, 66 pp.

Kärhä K., Kortelainen E., Karjalainen A., Haavikko H., Palander T. 2023. Fuel consumption of a high-capacity transport (HCT) vehicle combination for industrial roundwood hauling: a case study of laden timber truck combinations in Finland. International Journal of Forest Engineering, 284–293.

Kizha A.R., Han H-S. 2015. Forest residues recovered from whole-tree timber harvesting operations. European Journal Forest Engineering 1 (2), 46–55.

Kühmaier M., Kral I., Kanzian C. 2022. Greenhouse gas emissions of the forest supply chain in Austria in the year 2018. Sustainability 14, 792.
https://doi.org/10.3390/su14020792

Moskalik T., Gendek A. 2019. Production of chips from logging residues and their quality for energy: a review of European literature. Forests 10 (3), 262.
https://doi.org/10.3390/f10030262

Röser D., Mola-Yudego B., Prinz R., Emer B., Sikanen L. 2012. Chipping Operations and Efficiency in Different Operational Environments. http://www.metla.fi/silvafennica/full/sf46/sf462275.pdf276

Small R., Ghaffariyan M.R. 2023. A short literature review on sawlog and pulpwood transport efficiency and fuel consumption. European Journal of Forest Engineering 9 (1), 41–47.

Spinelli R., Hartsough B. 2001. A survey of Italian chipping operations. CNR – Consiglio Nazionale delle Ricerche, 112 pp.

Svenson G., Fjeld D. 2016. The impact of road geometry and surface roughness on fuel consumption of logging trucks. Scandinavian Journal of Forest Research, 526536.